Philosophy, Policies, and Procedures: The Three P's of Flight-Deck Operations

Asaf Degani
San Jose State University Foundation
San Jose, California

Earl L. Wiener
University of Miami
Coral Gables, Florida

ABSTRACT

Standard operating procedures are drafted and provided to flightcrews to dictate the manner in which tasks are carried out. Failure to conform to Standard Operating Procedures (SOP) is frequently listed as the cause of violations, incidents, and accidents. However, procedures are often designed piecemeal, rather than being based on a sound philosophy of operations and policies that follow from such a philosophy. A framework of philosophy, policies, and procedures is proposed.

INTRODUCTION

A complex human-machine system is more than a collection of hardware and software components. In order to operate successfully it must be supported by an organizational infrastructure of "philosophy of operations" and company policies that include documents such as procedures, checklists, manuals, instructions, etc. In a previous study (Degani & Wiener, 1990), we examined the use of the normal flight-deck checklist in the airline industry; we will now examine the role of procedures.

In 1988, Lautman and Gallimore conducted a study of aircraft accident reports to "better understand accident cause factors" in commercial airline operations. They analyzed 93 accidents that occurred between 1977-1984. The leading crew-caused factor was "pilot deviation from basic operational procedures" (33%). The "rash" of configuration and checklist-related accidents that the airline industry has witnessed in the last three years (Degani & Wiener, 1990; National Transportation Safety Board, 1988; 1989; 1990) clearly support the findings of Lautman and Gallimore.

With respect to checklist usage, our previous findings indicated that there are two fundamental factors that generate the "pilot deviation from basic operational procedures" classification. The first, of course, is the fact that humans may ignore or misuse procedures. The second factor, which lies beneath the surface, concerns the philosophy behind, and the design of such procedures (Degani & Wiener, 1990).

This paper will focus on the second, yet less explicit factor: the philosophy, policy, and the design of cockpit procedures. It is our position that the first and second factors are strongly interrelated. Failure to develop an overall philosophy and set of policies that are consistent with each other, and procedures that are consistent with both, will lead flight crews to deviate from Standard Operating Procedures (SOP). In most cases, these deviations will be harmlessly absorbed by the entire system and its embedded redundancies. Yet from time to time, unpredicted interactions of failures and deviations will manifest themselves in an accident.

Procedures

A procedure is a specification for conducting a set of predetermined sub-tasks (or actions) that are components of a higher level task. The function of a well-designed flight-deck procedure is to assist, dictate and specify a progression of sub-tasks (or actions) to ensure that the task at hand will be carried out in a manner that is logical, efficient, and also error resistant. A procedure also serves to provide a common ground for two or three individuals (comprising a flight crew) that at times may be totally unfamiliar with each other's technical capabilities.

At this point we must make a distinction between checklist and procedure as the two are often confused. A checklist is a device (paper, mechanical, audio, or electronic format) that exists to ensure that procedures are carried out. The confusion may come from the fact that "running" a checklist is in itself a procedure.

Philosophy and Policy

Procedures do not fall from the sky, nor are they inherent in the equipment. They are based on a broad concept of operation. We believe that there is a link between procedures and philosophy. We call it "The three P's of operations": philosophy, policies, and procedures. The design of any procedure should begin with first developing an overall guiding philosophy of flight operations that states how flight management wants its airline to function. This step is often ignored, or brushed off with statements such as "safety comes first." The emergence of flight-deck automation has recently generated an interest in philosophy, partly due to lack of agreement about how and when automatic features are to be used, and who may make that decision (Wiener, 1988). This led one carrier, Delta Air Lines, to develop a one-page formal statement of automation philosophy (Reprinted in Wiener, et al., 1991).

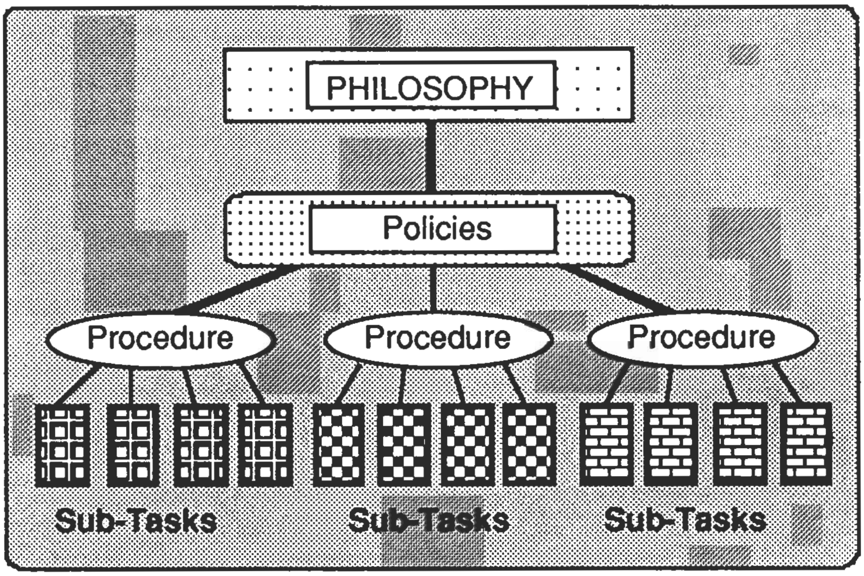

Figure 1. *Framework of the three P's of operations*

The philosophy in turn generates policies. Policies are broad specifications of the manner in which management expects things to be done (training, flying, maintenance, exercise of authority, personal conduct, etc.). Procedures, then, must be designed to be consistent with the policies, which must be consistent with the overall guiding philosophy. Figure 1 depicts this framework.

The procedures, finally, determine how tasks will be accomplished. If flight management attempts to shortcut the three P's process by jumping right into procedure writing, the risk is a set of ill-conceived and inconsistent procedures.

To illustrate the Three P's, let us assume that the task at hand is the configuration of the aircraft for a Category-I ILS approach:

(1) Philosophy: Automation is just another tool to help the pilot.
(2) Policy: Use or non-use of automatic features (within reason) is at the discretion of the crew.
(3) Procedure: On a Category-I approach, the flight crew will first decide what level of automation to use (hand-fly with flight director; autopilot and mode control panel; coupled; etc.), which determines what must be done to configure the cockpit.
(4) Sub-tasks (or actions): Follow from procedures (e.g., tune and identify localizer and compass locator, set decision height, select autopilot mode, etc.)

Standardization

Standardization is the palace guard of procedures. It is a management function which begins with the writing of procedures, to ensure that they are consistent with the philosophy and policies, and are technically correct. Standardization also extends to various quality control methods that ensure that the procedures are carried out. These methods include recurrent training, LOFT, line and simulator check rides.

DESIGN PROBLEMS

Incompatibility of the Procedure with the Operational Environment

Philosophies, policies, and procedures cannot be developed and designed without regard for the operational environment in which they will be used. The procedures associated with configuring the aircraft at the gate are particularly sensitive to the environment in which the flight crew and the aircraft operate.

External agents. Certain cockpit tasks are dependent on the activities of external agents such as flight attendants, gate agents, fuelers, etc. When considering the chronological and logical sequence of the procedure, the influence of these entities on procedure design, implementation, and task completion must be considered.

An elaborate configuration procedure such as the BEFORE ENGINE START, that includes items that do not run "parallel" to the activities occurring around the plane, has inherent timing and scheduling deficiencies. Deferment of a sub-task (or action) usually occurs when it cannot be completed in its specific sequence due to activities external to the cockpit and therefore beyond the control of the crew. Due to the limitations of human memory, coupled with time constraints, workload, and the vulnerability of the crew to distracting events, the likelihood of this sub-task being forgotten is relatively high. One Aviation Safety Reporting System (ASRS) report speaks to the matter:

> Prior to departure from Denver, as the preflight checklists were being accomplished, it was noted that the plane was not fueled yet. The crew continued [deferred the item for later completion] in accomplishing the rest of the checklist and related preflight duties. Approximately ten minutes after takeoff the second officer noted that the plane was not fueled. The flight returned to Denver for additional fuel. At company Denver facilities, experience dictates that dispatch fuel is not on board prior to completion of the preflight checklist in approximately 75% of departures... (ASRS, 1987, report #28551)

Type of operation. A somewhat different example of the incompatibility of procedures, usually caused by the lack of a proper policy, is the effect of long- and short-haul operation on checklist usage. Pilots who fly short flight segments perform the normal flight checklists as much as 3-8 times per day and as many as 12-33 times on a typical trip. A requirement to conduct a very long and meticulous checklist for each flight may lead some to deviate from the prescribed procedures, performing only what he/she perceives as the critical items. For example, one U.S. company used its DC-9-50 fleet for very short legs, yet, many legs per day. The aircraft checklist contained 81 check items for the ground phase checks (ENGINE START through TAKEOFF). Not surprisingly, pilots from this company expressed concern about poor procedural discipline in short-haul operations (Degani & Wiener, 1990).

Ergonomic layout of the cockpit. Much like the problem of incompatibility with the operational environment, we noted incompatibility of procedures with the ergonomics of the flight deck: for example, the flap/slat and gear levers. Traditionally, gear and flap/slat levers are located in the first officer area (right side of the cockpit). It is not within an easy reach for the captain in a cockpit of a wide body airplane. In most U.S. airlines the captain and the first officer rotate the duties of pilot flying (PF) and pilot not flying (PNF) during a trip. If the first officer is the PF the procedure may demand that the captain raise the gear and flaps/slats after takeoff. In this case the captain must lean to the right of the throttle quadrant to grasp the gear or flap/slat lever(s). The captain cannot see the flap/slat detents very well and he may also accidentally bump the throttles and associated controls (TOGA, and fuel switches). The same may occur when the first officer, as the PF, wants to use the speed-brakes located to the left of the throttle quadrant.

We believe that if the procedure is to be used efficiently, the environment should support it, not restrict it. The designers of the Airbus A-320 eliminated a portion of this incompatibility by placing the speed brakes and flap levers on the pedestal between the two pilots. Obviously another approach would be to change the procedure by allowing the first officer (PF) to raise the gear. This approach, however, might be contradictory to a common policy that on takeoff the PF should do nothing but fly the airplane.

Sequential Incompatibility

Sequencing is the internal mechanism that drives many cockpit procedures, especially critical procedures which are usually time dependent. Sometimes the only reason for a procedure is the absolute necessity of a correct sequencing of actions. In a previous study (Degani & Wiener, 1990), we found sequential deficiencies in the *normal* procedures of several U.S. carriers, in which the procedural flow becomes intermittent (as opposed to consistent) in the motor movement of eyes, head, arms and hands along the panels in the cockpit. Furthermore, in some cases the geographic flow pattern itself was very different from the sequence of the checklist items.

We have also found similar deficiencies in abnormal/emergency procedures. With respect to emergency procedures, these deficiencies are very critical because of the time limitation, workload, and level of stress involved in dealing with the situation. In addition, these checklists are mostly performed as "actions lists," i.e., an item is read (or recalled from memory) and immediately performed. In this case a sequential mistake can lead a crewmember to make an irreversible action.

For example, consider the immediate action procedure for an IRREGULAR START for one medium-range aircraft (Figure 2):

IMMEDIATE ACTION

FUEL CONTROL SWITCH . . . . CUTOFF

ENGINE START SELECTOR . . . . GND
Motor for 30 seconds or until EGT is below 180, whichever is longer (unless no oil pressure).

NOTE
If starter cutout has occurred, reselect GND when N_2 is below 20%.

If problem was other rapid EGT rise:

ENGINE START SELECTOR . . . . OFF

Figure 2. *IRREGULAR START procedure*

If the procedure is carried out in the sequence listed, then the flight crew may overlook the restriction and select "ground" (GND) when N2 is above 20%. A simple solution, used by some pilots, is to add the restriction in pen/pencil before the word GND. We note that, while one's intention may be the best, writing on, and thereby modifying, the checklist card is a violation of FAR 121.315, though it is not an uncommon practice. The dangers of using such "custom built" procedures are quite obvious.

We attempted to obtain information about problems with emergency and abnormal procedures by conducting a preliminary study on the Aviation Safety Reporting System database (ASRS, 1989). However, the ASRS database by itself was simply not sensitive enough to provide information about problems with such procedures, mainly because of the low frequency of such incidents. Therefore, to obtain this type of information, we conducted a structured callback study utilizing the ASRS program. In this data collection methodology the researcher calls back the reporter (who filed an ASRS report) in order to obtain information beyond that which appears on the reporting form (Orlady & Wheeler, 1989). We telephoned pilots who reported emergency and abnormal incidents to the ASRS program between December 1989 and March 1990.

This effort revealed mostly sequential deficiencies in abnormal/emergency procedures of Part 121 operators. One reporter detailed an incident in which a medium-range trijet experienced a rapid decompression at 35,000 feet. The flight engineer followed the procedural flow that began at the top of the panel, checked the pack-trip switch, and worked his way down to the manual pressurization control (out-flow valve). By this time the cabin was ascending rapidly (to 17,000 feet). The reporter indicated that most "seasoned" flight engineers would first reach for the over-flow valve (in an attempt to arrest the cabin ascent) and only then check the panel. However, the F/E on that flight, being new on the job "*just followed the procedure as written in the book.*" (callback based on ASRS report #130178)

Incompatibility of Paperwork and Computerwork

The following example of paperwork-computerwork incompatibility comes from Wiener (1989). The crew of a B-757 flying from Miami to Washington National was dispatched with a computer-generated flight plan with the following route: "radar vectors, AR-1 CLB ILM J-40 RIC..." When the crew attempted to enter the flight plan into the Route page of the CDU, they got no further than CLB, which continually resulted in an error message of "not in database." They repeatedly tried to enter the flight plan and continued to receive the same message after entering CLB. What was the problem? CLB (Carolina Beach) is a nondirectional beacon, not a VOR as the three-letter designator implied. The flight plan, to be correct and compatible with the "expectations" of the CDU should have read "CLBNB." It was not until the crew got out their paper charts and traced the route that the error in the flight plan was apparent.

Wording

The words used in operating procedures are also an important factor in reducing the likelihood of incidents or accidents. A consistent and unambiguous phraseology of flight-deck procedures is critical for preventing misunderstanding (Degani & Wiener, 1990). For example, the SOP for starting engines of a B-737/300 for one U.S. carrier is for the ground-crewmen to call the cockpit and say "Cleared to start engines." During line operations, however, most experienced ground-crewmen will give "clearance to start" per a specific engine, i.e., "cleared to start No. 1," or "cleared to start No. 2." Even the SOP states the need for a specific sequence: "Recommend starting No.1 engine first. Do not start No. 2 engine if bags/cargo are to be boarded..." Another reason for this sequence is that the tow-bar pin is extracted from the right side. Therefore, it is preferred not to have the right engine operating when the ground-crew is disconnecting the tow bar (note that this is an example of what we discussed previously about the influence of activities external to the cockpit).

In one incident a ground-crew trainee called the cockpit and told the captain "cleared to start engines" (exactly as SOP dictates). What he meant to say was "cleared to start No. 1," as other ground crews were loading bags on the right side of the aircraft. The captain later stated that the callout "just did not sound right." He did not start the engine and called the ground crewmen to verify if he is cleared to start any engine or just one of them. An accident in which the loading crew could have been injured by engine blast was prevented by the captain's skepticism. In this example the *correct* SOP callout was a potential "set up" for an incident/accident.

SOME COUNTERMEASURES

We have stated some of the problems and deficiencies with flight-deck procedures. We also believe that there are methods and techniques, already available, that can be employed to improve these procedures.

Procedures and the Interface

An interface, from our point of view, is the "bridge" by which humans and the machines interact to exchange information and "join forces" in order to accomplish a task. Traditionally, the human factors community has concentrated on the hardware and software interfaces in the cockpit, neglecting the procedural elements which the authors consider as part of the interface. Procedures, we believe, are part of the bridge between the pilot and the airplane's systems. They dictate the manner by which the pilot is expected to interact with the aircraft's systems. We suggest, therefore, that flight-deck procedures are a component of the *interface*.

Design of Procedures

If we accept the notion that procedures are a component of the interface, then we should apply to their design the same methods the human factors discipline is well versed in: task analysis and experimentation.

Task analysis. This is a methodology that can aid the designer by describing, placing, and sequencing all the sub-tasks (or actions) that must be performed to carry out a task and later comparing these demands with known human capabilities and limitations (Drury, Paramore, Van Cott, Grey & Corlett, 1987; Sanders & McCormick, 1987). In addition to the traditional methods of task analysis, the designer may use a pseudo "bottom-up" approach by asking himself/herself what specific human actions and machine output are required to result from a procedure. Only then, can the designer "compose" the procedure piece by piece so that it will produce the desired actions in a logical, efficient, and error resistant manner. An example of the hazards of not proceeding in a bottom-up manner can be seen in Figure 2.

Experimentation. We strongly recommend that normal procedures and other critical flight-deck procedures, such as engine fire/failure and the like, should be validated experimentally by testing them against the *behavior* of pilots, and not the judgment of others. The experimentation should take place in the appropriate flight simulator using a true sample of the target population, i.e., *line* pilots, as opposed to management pilots. The dependent variables such as completion, duration, correctness, subjective ratings, workload ratings, etc., should be analyzed to determine the optimum results. Evaluation in a Line Oriented Simulation (LOS) environment can go a long way in demonstrating potential "pitfalls" of procedures under evaluation (Palmer & Degani, 1991). This process can be costly and time consuming, but the price of not doing it can be even worse.

CONCLUSIONS

The procedure designer can never relax. Flight-deck procedures are "dynamic": they constantly change, reflecting operational changes, such as new regulations, new equipment, new routes, new gates, ground crew procedures etc. For example, the new passenger smoking rule necessitated a change in cockpit procedures, as the "no smoking" sign was also a signal to the flight attendants to prepare the cabin for landing. New rule--new procedures.

We believe that flight management should closely monitor procedural adequacy and compatibility with the operational environment. Incompatible procedures should be modified or changed; otherwise there is a chance that the procedure will appear as a nuisance to the flight crews. When this happens, not only does that specific procedure suffer, but also cockpit performance in general. What is worse, a procedure that is poorly designed or out of date can induce a failure, an incident, or an accident.

We suggest that it is time that the industry take a new look at the all too common classification of "pilot deviation from SOP." The questions we must ask are whether these procedures were adequate for the task? Were they compatible with every part of the system? Were they part of a consistent framework of philosophy and policies? Was there something in the design or the manner in which a procedure was used that led a responsible flight crewmember to deviate from a procedure that is in place to protect him/her from a catastrophe?

In 1947 Fitts and Jones published the results of an analysis of factors contributing to 460 "*pilot error*" experiences in operating aircraft controls. They wrote: "It should be possible to eliminate a large portion of so-called 'pilot error' accidents by designing equipment in accordance with human requirements" (Fitts & Jones, 1947, p. 47). Fitts and Jones have pointed out that it is a gross over-simplification to describe so many accidents as "pilot error." We suggest that the same can be said of the phrase "pilot deviation from standard operating procedures."

ACKNOWLEDGMENT

This research was supported by NASA Ames Research Center Grants NCC2-327 to the San Jose State University Foundation and Grant NCA2-441 to the University of Miami. The authors gratefully acknowledge the support of the NASA ASRS office, America West Airlines, and Delta Air Lines. The authors thank Sheryl L. Chappell, Kevin M. Corker, Michael S. Hayes, Harry W. Orlady, Everett A. Palmer, and Michael H. Smiley for reviewing this document and providing helpful comments.

REFERENCES

ASRS. (1987). *Erroneous flap setting; checklist use* (Special request No. 1177/1182 [Database search]). ASRS office, Mountain View, California: Battelle.

ASRS. (1989). *Incidents involving the use of abnormal and emergency procedures* (Special request, available from authors). ASRS office, Mountain View, California: Battelle.

Degani, A., & Wiener, E. L. (1990). *The human factors of flight-deck checklists: The normal checklist* (NASA contractor report 177549). Moffett Field, CA: NASA Ames Research Center.

Drury, C. G., Paramore, B., Van Cott, H. P., Grey, S. M., & Corlett, E. N. (1987). Task Analysis. In G. Salvendy (Ed.), *Handbook of human factors* (pp. 370-401). New York: John Wiley & Sons.

Fitts, P. M., & Jones, R. E. (1947). *Analysis of factors contributing to 460 "pilot-error" experiences on operating aircraft controls* (TSEAA-694-12). Wright-Patterson AFB, OH: Aero Medical Laboratory.

National Transportation Safety Board. (1988). *Northwest Airlines. DC-9-82 N312RC, Detroit Metropolitan Wayne County Airport. Romulus, Michigan. August 16, 1987* (Aircraft accident report, NTSB/AAR-88/05). Washington, DC: Author.

National Transportation Safety Board. (1989). *Delta Air Lines, Boeing 727-232, N473DA. Dallas-Fort Worth International Airport, Texas. August 31, 1988* (Aircraft accident report, NTSB/AAR-89/04). Washington, DC: Author.

National Transportation Safety Board. (1990). *USAir, Inc., Boeing 737-400, N416US. LaGuardia Airport. Flushing, New York. September 20, 1989* (AAR-90/03). Washington, DC: Author.

Orlady, H. W., & Wheeler, W. A. (1989). Training for advanced technology aircraft. *Proceedings of the Fifth International Symposium on Aviation Psychology*, (pp. 91-96). Columbus, OH: Ohio State University

Palmer, E. A., & Degani, A. (1991). *Configuration system I.* (NASA technical memo [work in progress]). Moffett Field, CA: NASA Ames Research Center.

Sanders, M. S., & McCormick, E. J. (1987). *Human factors in engineering and design* (6th ed.). New York: McGraw-Hill.

Wiener, E. L. (1988). Cockpit automation. In E. L. Wiener, & D. C. Nagel (Eds.), *Human factors in aviation* (pp. 433-461). San Diego: Academic Press.

Wiener, E. L. (1989). *The human factors of advanced technology ("glass cockpit") transport aircraft* (NASA contractor report 177528). Moffett Field, CA: NASA Ames Research Center.

Wiener, E. L., Chidester, T. R., Kanki, B. G., Palmer, E. A., Curry, R. E., & Gregorich, S. E. (1991). *The impact of cockpit automation on crew coordination and communication: I. Overview, LOFT evaluations, error severity, and questionnaire data* (NASA Contractor Report [in press]). Moffett Field, CA: NASA Ames Research Center.